# Synopsis V1.0 Proton SEE Test of Gflx Process SRAM Test Vehicle from LSI Logic

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## I. Introduction

This study was undertaken to determine the proton induced single event destructive and transient susceptibility of the LSI Logic Gflx standard process and two versions of Gflx radiation hardened process. The test vehicle is a SRAM. The device under test (DUT) was monitored for single event upset (SEU) and for destructive events induced by exposing it to a proton beam at the Indiana University Cyclotron Single Event Effects Test Facility.

## II. Devices Tested

LSI Logic Gflx standard technology is a  $0.11~\mu m$  CMOS bulk process. The two versions of the radiation-hardened process include a buried layer in order to guarantee SEL immunity.

The SRAM test vehicle L9B0422 (RAM187 high density module and RAM249 high speed module) is a 4Mbit SRAM organized as 512K\*8 bits externally. The test vehicle uses internally 16 256Kbit memory megacells. The core SRAM cell is a 6-transistor cell. The memory core supply voltage is 1.2V, and the I/O supply voltage is 2.5V. The SRAM test vehicle is packaged in a 64 pin plastic quad flat pack (PQFP) (code UC36).

The test samples' package markings are shown in tables 1 and 2.

Table 1: RAM249 test samples

Test vehicle	Process	Marking	SN#
RAM249	Standard (ctrl)	LSI Logic	2
		L9B0421	
		GAH15900.14	
		ETH27001.1	
		Control B2	
		24	
		G 0528 Δ	
		Korea	
	Buried layer 1 (Dose 5)	LSI Logic	19
		L9B0421	
		GAH15900.14	
		ETH27001.1	
		1.6M5E14B2	
		12	
		G 0528 Δ	
		Korea	
	Buried layer 2 (Dose 1)	LSI Logic	32, 36
		L9B0421	
		GAH15900.14	
		ETH27001.1	
		1.6M1E14B2	
		7	
		G 0528 Δ	
		Korea	

Table 2: RAM187 test samples

Test vehicle	Process	Marking	SN#
RAM187	Standard (ctrl)	LSI Logic	51
		L9B0421	
		GAH15900.14	
		ETH27002.1	
		Control BR	
		24	
		G 0528 Δ	
		Korea	
	Buried layer 1 (Dose 5)	LSI Logic	66
		L9B0421	
		GAH15900.14	
		ETH27002.1	
		1.6M5E14BR	
		12	
		G 0528 Δ	
		Korea	
	Buried layer 2 (Dose 1)	LSI Logic	82
		L9B0421	
		GAH15900.14	
		ETH27002.1	
		1.6M1E14BR	
		7	
		G 0528 Δ	
		Korea	

# III. Test Facility

Facility: Indiana University Cyclotron Facility (IUCF), Bloomington, IN

**Energy:** 200 MeV, 104 MeV

Flux:  $1 \times 10^7$  to  $1 \times 10^8$  particles/cm<sup>2</sup>/s depending on device sensitivity.

**Fluence:** All tests will be run to 1 x 10<sup>10</sup> p/cm<sup>2</sup> or until destructive at least 100 SEU

occurred.

## IV. Test Conditions and Error Modes

**Test Temperature:** Room Temperature **Operating Frequency:** static, dynamic 10 MHz

**Power Supply Voltage:** memory core: 1.2V, I/Os: 2.5V

**PARAMETERS OF INTEREST:** Power supply currents, device functionality

**SEE Conditions:** SEL, SEU, MEU, SET

### V. Test Methods

Both test vehicles were tested with NASA-GSFC REAG (Radiation Effects and Analysis Group) Low Cost Digital Tester (LCDT). LCDT is a reusable universal digital device tester based on Xilinx Spartan 3 Field Programmable Gate Array (FPGA) with input/output (I/O) operation speed up to 200 MHz.

LCDT is the main test board that interfaces with the DUT-specific daughter card. The DUT on the daughter card is exercised using the configurable FPGA on LCDT with Hardware Design Language such as VHDL based coding. A remote PC controls LCDT. Figure 1 shows the LCDT with the SRAM daughter board.

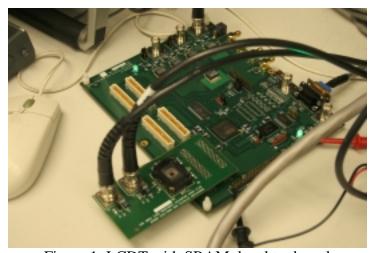


Figure 1: LCDT with SRAM daughter board

During irradiation, DUT power supply currents (core and I/Os) were monitored. As soon as on of the current reaches a programmable (20 mA for the core, 10 mA for I/Os) SEL detection level, the DUT power supplies were shutdown.

SRAM test vehicle was tested under two different test conditions:

- static test: a test pattern is loaded in the DUT before irradiation. DUT is irradiated. Then, it is checked after the end of the irradiation run.
- Dynamic test: a test pattern is loaded in the DUT before irradiation. During irradiation DUT is continuously read and errors are corrected in real time. Error information (address, data read, expected data) is stored for further analysis (MEU, stuck bits,..). Figure 2 below shows the dynamic test flow diagram.

Four different test patterns were used: all0, all1, logical checkerboard, and reverse logical checkerboard.

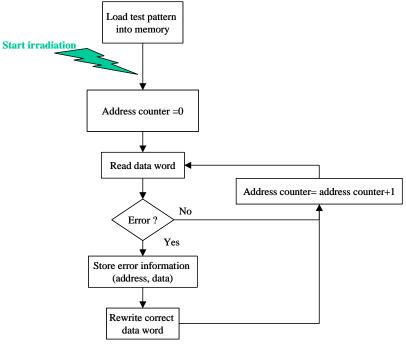


Figure 2: dynamic test flow diagram

#### VI. Test results

Detailed test results are given in Appendix. Test data showed little part-to-part variation, no test condition effect, static versus dynamic, and little effect on test pattern. Results presented below are average results between test samples and test patterns. No micro lachup event was observed during proton tests. Protons SEU cross sections are shown in Figure 3. We can see that both RAM designs have a similar SEU sensitivity. The maximum measured cross section is about 2 10<sup>-14</sup> cm<sup>2</sup>/bit.

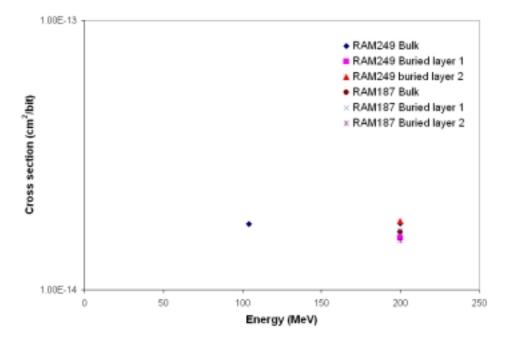


Figure 3: proton SEU cross-section curve

# **Reference documents:**

- "Gflx SRAM Test Chip Design MEMPQV," file MEMPQV\_spec.pdf, Nov 1, 2001.
- "Low cost digital tester hardware manual," 2005.

# **Appendix: Test Results**

19   249 bulk   2   static   all   200   5.00E+09   333   6.66E-08   80 deg in   20   249 bulk   2   dynamic   all   200   5.00E+09   375   7.50E-08   80 deg in   21   249 bulk   2   static   all   200   5.00E+09   364   7.28E-08   80 deg in   22   249 BL2   32   dynamic   all   200   5.00E+09   332   6.64E-08   23   249 BL2   32   static   all   200   5.00E+09   382   7.64E-08   26   249 BL1   19   dynamic   all   200   5.00E+09   322   6.44E-08   27   249 BL1   19   dynamic   all   200   5.00E+09   314   6.28E-08   28   249 BL1   19   static   all   200   5.00E+09   344   6.88E-08   29   249 BL1   19   static   all   200   5.00E+09   332   6.64E-08   30   249 BL2   36   dynamic   all   200   5.00E+09   332   6.64E-08   31   249 BL2   36   dynamic   all   200   5.00E+09   330   6.60E-08   31   249 BL2   36   static   all   200   5.00E+09   416   8.32E-08   32   249 BL2   36   static   all   200   5.00E+09   300   7.80E-08   31   87   bulk   51   dynamic   all   200   5.00E+09   323   6.46E-08   31   87   bulk   51   dynamic   all   200   5.00E+09   323   6.46E-08   37   187   bulk   51   static   all   200   5.00E+09   343   6.86E-08   37   187   bulk   51   static   all   200   5.00E+09   343   6.86E-08   38   187   bulk   51   static   all   200   5.00E+09   343   6.86E-08   38   187   bulk   51   static   all   200   5.00E+09   343   6.86E-08   38   187   bulk   51   static   all   200   5.00E+09   347   6.74E-08   39   187   BL2   82   dynamic   all   200   5.00E+09   337   6.74E-08   39   187   BL2   82   dynamic   all   200   5.00E+09   347   6.94E-08   41   187   BL2   82   static   all   200   5.00E+09   347   6.94E-08   44   187   BL2   82   static   all   200   5.00E+09   347   6.94E-08   44   187   BL1   66   dynamic   all   200   5.00E+09   347   6.94E-08   45   187   BL1   66   dynamic   all   200   5.00E+09   354   7.08E-08   46   187   BL1   66   dynamic   all   200   5.00E+09   360   7.20E-08   46   187   BL1   66   dynamic   all   200   5.00E+09   360   7.20E-08   47   187   BL1   66   dynam	Comment	Xsec	SEU	Fluence	Energy	Pattern	Test mode	SN	Process	Run
7         249 bulk         2         static         all1         200         1.25E+09         111         8.88E-08           8         249 bulk         2         dynamic         all0         200         5.00E+09         318         6.36E-08           9         249 bulk         2         dynamic         all0         200         5.00E+09         311         6.22E-08           10         249 bulk         2         dynamic         alla         200         5.00E+09         393         7.66E-08           14         249 bulk         2         dynamic         all1         200         5.00E+09         365         7.30E-08           15         249 bulk         2         dynamic         all0         200         5.00E+09         365         7.30E-08           16         249 bulk         2         dynamic         all0         200         5.00E+09         365         7.30E-08           18         249 bulk         2         dynamic         all0         200         5.00E+09         325         6.50E-08         80 deg in           19         249 bulk         2         static         all1         200         5.00E+09         325         6.50E-08					` '					#
8         249 bulk         2         dynamic         all0         200         5.00E+09         318         6.36E-08           9         249 bulk         2         static         all0         200         5.00E+09         311         6.22E-08           10         249 bulk         2         dynamic         aaaa         200         3.12E+09         201         6.44E-08           13         249 bulk         2         static         aaaa         200         5.00E+09         383         7.66E-08           15         249 bulk         2         dynamic         all1         200         5.00E+09         335         7.30E-08           16         249 bulk         2         dynamic         all0         200         5.00E+09         438         8.06E-08           17         249 bulk         2         dynamic         all1         200         5.00E+09         325         6.50E-08         80 deg in           19         249 bulk         2         dynamic         all1         200         5.00E+09         325         6.50E-08         80 deg in           21         249 bulk         2         static         all0         200         5.00E+09         337							·			
9 249 bulk   2 static   alilo   200   5.00E+09   311   6.22E-08										
10 249 bulk   2   dynamic   aaaa   200   3.12E+09   201   6.44E-08     13 249 bulk   2   dynamic   all1   200   5.00E+09   383   7.66E-08     14 249 bulk   2   dynamic   all1   200   5.00E+09   393   7.86E-08     15 249 bulk   2   dynamic   all1   200   5.00E+09   365   7.30E-08     16 249 bulk   2   dynamic   all0   200   5.00E+09   418   8.36E-08     17 249 bulk   2   static   all1   200   5.00E+09   403   8.06E-08     18 249 bulk   2   dynamic   all1   200   5.00E+09   325   6.50E-08   80 deg in     19 249 bulk   2   dynamic   all0   200   5.00E+09   333   6.66E-08   80 deg in     20 249 bulk   2   dynamic   all0   200   5.00E+09   375   7.50E-08   80 deg in     21 249 bulk   2   static   all0   200   5.00E+09   375   7.50E-08   80 deg in     22 249 BL2   32   dynamic   all11   200   5.00E+09   364   7.28E-08   80 deg in     23 249 BL2   32   static   all10   200   5.00E+09   382   7.64E-08     26 249 BL1   19   dynamic   all10   200   5.00E+09   382   7.64E-08     27 249 BL1   19   dynamic   all10   200   5.00E+09   382   7.64E-08     28 249 BL1   19   static   all11   200   5.00E+09   322   6.44E-08     29 249 BL1   19   static   all11   200   5.00E+09   322   6.44E-08     30 249 BL2   36   dynamic   all11   200   5.00E+09   331   6.68E-08     31 249 BL2   36   dynamic   all11   200   5.00E+09   314   6.28E-08     32 249 BL2   36   dynamic   all11   200   5.00E+09   300   6.60E-08     33 249 BL2   36   dynamic   all11   200   5.00E+09   310   6.60E-08     34 187 bulk   51   dynamic   all11   200   5.00E+09   310   6.60E-08     35 187 bulk   51   dynamic   all11   200   5.00E+09   300   7.80E-08     36 187 bulk   51   static   all11   200   5.00E+09   300   7.80E-08     37 187 bulk   51   static   all10   200   5.00E+09   300   6.18E-08     39 187 BL2   82   dynamic   all10   200   5.00E+09   300   6.18E-08     40 187 BL2   82   dynamic   all10   200   5.00E+09   300   6.18E-08     41 187 BL2   82   dynamic   all10   200   5.00E+09   300   6.18E-08     44 187 BL1   66   dynamic   all11   200   5.00E+09		6.36E-08		5.00E+09		all0	dynamic			
13 249 bulk   2 static   aaaa   200   5.00E+09   383   7.66E-08     14 249 bulk   2 dynamic   all1   200   5.00E+09   393   7.86E-08     15 249 bulk   2 static   all1   200   5.00E+09   365   7.30E-08     16 249 bulk   2 dynamic   all0   200   5.00E+09   418   8.36E-08     17 249 bulk   2 static   all1   200   5.00E+09   418   8.36E-08     18 249 bulk   2 dynamic   all1   200   5.00E+09   433   8.06E-08     19 249 bulk   2 static   all1   200   5.00E+09   333   6.66E-08   80 deg in     19 249 bulk   2 static   all1   200   5.00E+09   375   7.50E-08   80 deg in     20 249 bulk   2 dynamic   all0   200   5.00E+09   375   7.50E-08   80 deg in     21 249 bulk   2 static   all1   200   5.00E+09   364   7.28E-08   80 deg in     22 249 BL2   32 dynamic   all1   200   5.00E+09   332   6.64E-08     23 249 BL2   32 static   all1   200   5.00E+09   382   7.64E-08     249 BL1   19 dynamic   all10   200   5.00E+09   322   6.44E-08     25 249 BL1   19 dynamic   all10   200   5.00E+09   322   6.44E-08     26 249 BL1   19 static   all11   200   5.00E+09   344   6.28E-08     28 249 BL1   19 static   all11   200   5.00E+09   344   6.28E-08     29 249 BL1   19 static   all10   200   5.00E+09   332   6.66E-08     30 249 BL2   36   dynamic   all11   200   5.00E+09   332   6.66E-08     31 249 BL2   36   dynamic   all11   200   5.00E+09   344   6.28E-08     32 249 BL2   36   static   all10   200   5.00E+09   330   6.60E-08     33 249 BL2   36   static   all10   200   5.00E+09   375   7.80E-08     34 187 bulk   51   dynamic   all11   200   5.00E+09   300   6.60E-08     35 187 bulk   51   dynamic   all11   200   5.00E+09   300   6.0E-08     36 187 bulk   51   dynamic   all11   200   5.00E+09   309   6.18E-08     36 187 bulk   51   dynamic   all11   200   5.00E+09   309   6.18E-08     37 187 bulk   51   dynamic   all11   200   5.00E+09   309   6.18E-08     38 187 bulk   51   dynamic   all11   200   5.00E+09   309   6.18E-08     38 187 bulk   51   dynamic   all10   200   5.00E+09   309   6.18E-08     38 187 bulk   51   dynamic   all11		6.22E-08	311	5.00E+09	200	all0	static	2	249 bulk	9
14   249 bulk   2   dynamic   all   200   5.00E+09   393   7.86E-08		6.44E-08	201	3.12E+09	200	aaaa	dynamic	2	249 bulk	10
15 249 bulk   2 static   all   200   5.00E+09   365   7.30E-08   16 249 bulk   2 dynamic   all   200   5.00E+09   418   8.36E-08   17 249 bulk   2 static   all   200   5.00E+09   403   8.06E-08   18 249 bulk   2 dynamic   all   200   5.00E+09   325   6.50E-08   80 deg in   19 249 bulk   2 static   all   200   5.00E+09   335   6.66E-08   80 deg in   20 249 bulk   2 dynamic   all   200   5.00E+09   375   7.50E-08   80 deg in   20 249 bulk   2 static   all   200   5.00E+09   375   7.50E-08   80 deg in   21 249 bulk   2 static   all   200   5.00E+09   375   7.50E-08   80 deg in   22 249 BL2   32 dynamic   all   200   5.00E+09   332   6.64E-08   80 deg in   22 249 BL2   32 dynamic   all   200   5.00E+09   332   6.64E-08   80 deg in   22 249 BL1   19 dynamic   all   200   5.00E+09   332   6.44E-08   22 249 BL1   19 dynamic   all   200   5.00E+09   332   6.44E-08   22 249 BL1   19 dynamic   all   200   5.00E+09   332   6.44E-08   22 249 BL1   19 static   all   200   5.00E+09   344   6.88E-08   22 249 BL1   19 static   all   200   5.00E+09   332   6.64E-08   30 249 BL2   36 dynamic   all   200   5.00E+09   332   6.64E-08   31 249 BL2   36 dynamic   all   200   5.00E+09   330   6.60E-08   33 249 BL2   36 static   all   200   5.00E+09   330   6.60E-08   33 249 BL2   36 static   all   200   5.00E+09   330   6.46E-08   33 249 BL2   36 static   all   200   5.00E+09   330   6.46E-08   33 187 bulk   51 dynamic   all   200   5.00E+09   330   6.46E-08   33 187 bulk   51 dynamic   all   200   5.00E+09   330   6.46E-08   33 187 bulk   51 dynamic   all   200   5.00E+09   330   6.46E-08   33 187 bulk   51 static   all   200   5.00E+09   330   6.46E-08   34 187 bulk   51 static   all   200   5.00E+09   309   6.18E-08   34 187 bulk   51 static   all   200   5.00E+09   309   6.18E-08   34 187 bulk   51 static   all   200   5.00E+09   309   6.18E-08   34 187 bulk   51 static   all   200   5.00E+09   309   6.18E-08   34 187 bulk   51 static   all   200   5.00E+09   309   6.18E-08   34 187 bulk   51 static   all   200   5.00E+09   309		7.66E-08	383	5.00E+09	200	aaaa	static	2	249 bulk	13
16   249 bulk   2   dynamic   all0   200   5.00E+09   418   8.36E-08   17   249 bulk   2   static   all0   200   5.00E+09   403   8.06E-08   80 deg in   19   249 bulk   2   static   all1   200   5.00E+09   325   6.50E-08   80 deg in   19   249 bulk   2   static   all1   200   5.00E+09   333   6.66E-08   80 deg in   20   249 bulk   2   dynamic   all0   200   5.00E+09   375   7.50E-08   80 deg in   21   249 bulk   2   static   all0   200   5.00E+09   364   7.28E-08   80 deg in   22   249 BL2   32   dynamic   all1   200   5.00E+09   332   6.64E-08   80 deg in   22   249 BL2   32   static   all1   200   5.00E+09   332   6.64E-08   32   249 BL1   19   dynamic   all1   200   5.00E+09   382   7.64E-08   32   249 BL1   19   dynamic   all1   200   5.00E+09   332   6.44E-08   32   249 BL1   19   static   all1   200   5.00E+09   344   6.28E-08   32   249 BL1   19   static   all1   200   5.00E+09   332   6.64E-08   32   249 BL2   36   dynamic   all1   200   5.00E+09   330   6.60E-08   31   249 BL2   36   dynamic   all1   200   5.00E+09   330   6.60E-08   32   249 BL2   36   static   all1   200   5.00E+09   340   8.20E-08   32   249 BL2   36   static   all1   200   5.00E+09   340   8.20E-08   32   249 BL2   36   static   all1   200   5.00E+09   340   8.20E-08   34   187 bulk   51   dynamic   all1   200   5.00E+09   323   6.46E-08   37   187 bulk   51   dynamic   all1   200   5.00E+09   343   6.86E-08   37   187 bulk   51   static   all1   200   5.00E+09   343   6.86E-08   37   187 bulk   51   static   all1   200   5.00E+09   369   7.38E-08   38   187 bulk   51   static   all1   200   5.00E+09   345   6.66E-08   34   187 BL2   82   dynamic   all1   200   5.00E+09   347   6.74E-08   34   187 BL2   82   dynamic   all1   200   5.00E+09   347   6.74E-08   34   187 BL2   82   dynamic   all1   200   5.00E+09   347   6.74E-08   34   187 BL2   82   dynamic   all1   200   5.00E+09   347   6.74E-08   34   187 BL2   82   dynamic   all1   200   5.00E+09   347   6.74E-08   34   187 BL2   66   dynamic   all1   200   5.00E+09   347   6.9		7.86E-08	393	5.00E+09	200	all1	dynamic	2	249 bulk	14
17         249 bulk         2         static         all0         200         5.00E+09         403         8.06E-08           18         249 bulk         2         dynamic         all1         200         5.00E+09         325         6.50E-08         80 deg in           19         249 bulk         2         static         all0         200         5.00E+09         375         7.50E-08         80 deg in           20         249 bulk         2         static         all0         200         5.00E+09         375         7.50E-08         80 deg in           21         249 bulk         2         static         all0         200         5.00E+09         382         7.64E-08         80 deg in           22         249 BL2         32         static         all1         200         5.00E+09         382         7.64E-08           26         249 BL1         19         dynamic         all0         200         5.00E+09         314         6.28E-08           27         249 BL1         19         static         all1         200         5.00E+09         334         6.64E-08           30         249 BL2         36         dynamic         all1         200		7.30E-08	365	5.00E+09	200	all1	static	2	249 bulk	15
18         249 bulk         2         dynamic         all1         200         5.00E+09         325         6.50E-08         80 deg in           19         249 bulk         2         static         all1         200         5.00E+09         333         6.66E-08         80 deg in           20         249 bulk         2         dynamic         all0         200         5.00E+09         375         7.50E-08         80 deg in           21         249 bulk         2         static         all0         200         5.00E+09         364         7.28E-08         80 deg in           22         249 BL2         32         dynamic         all1         200         5.00E+09         332         6.64E-08           23         249 BL1         19         dynamic         all0         200         5.00E+09         382         7.64E-08           26         249 BL1         19         dynamic         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19         static         all1         200         5.00E+09         332         6.64E-08           30         249 BL2         36         dynamic         all1         200 <td></td> <td>8.36E-08</td> <td>418</td> <td>5.00E+09</td> <td>200</td> <td>all0</td> <td>dynamic</td> <td>2</td> <td>249 bulk</td> <td>16</td>		8.36E-08	418	5.00E+09	200	all0	dynamic	2	249 bulk	16
19   249 bulk   2   static   all   200   5.00E+09   333   6.66E-08   80 deg in   20   249 bulk   2   dynamic   all   200   5.00E+09   375   7.50E-08   80 deg in   21   249 bulk   2   static   all   200   5.00E+09   364   7.28E-08   80 deg in   22   249 BL2   32   dynamic   all   200   5.00E+09   332   6.64E-08   23   249 BL2   32   static   all   200   5.00E+09   382   7.64E-08   26   249 BL1   19   dynamic   all   200   5.00E+09   322   6.44E-08   27   249 BL1   19   dynamic   all   200   5.00E+09   314   6.28E-08   28   249 BL1   19   static   all   200   5.00E+09   344   6.88E-08   29   249 BL1   19   static   all   200   5.00E+09   332   6.64E-08   30   249 BL2   36   dynamic   all   200   5.00E+09   330   6.60E-08   31   249 BL2   36   dynamic   all   200   5.00E+09   330   6.60E-08   31   249 BL2   36   static   all   200   5.00E+09   416   8.32E-08   32   249 BL2   36   static   all   200   5.00E+09   390   7.80E-08   34   187 bulk   51   dynamic   all   200   5.00E+09   323   6.46E-08   36   187 bulk   51   dynamic   all   200   5.00E+09   343   6.86E-08   37   187 bulk   51   static   all   200   5.00E+09   343   6.86E-08   38   187 bulk   51   static   all   200   5.00E+09   345   6.50E-08   38   187 bulk   51   static   all   200   5.00E+09   343   6.86E-08   38   187 bulk   51   static   all   200   5.00E+09   347   6.74E-08   38   187 bulk   51   static   all   200   5.00E+09   347   6.74E-08   38   187 bulk   51   static   all   200   5.00E+09   347   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   335   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   347   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   347   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   347   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   347   6.74E-08   34   187 BL2   82   static   all   200   5.00E+09   347   6.74E-08   34   187 BL1   66   dynamic   all   200   5.00E+09   347   6.94E-08   34   187 BL1   66   dynamic   all   200   5.00E+09   354		8.06E-08	403	5.00E+09	200	all0	static	2	249 bulk	17
20         249 bulk         2         dynamic         all0         200         5.00E+09         375         7.50E-08         80 deg in           21         249 bulk         2         static         all0         200         5.00E+09         364         7.28E-08         80 deg in           22         249 BL2         32         dynamic         all1         200         5.00E+09         332         6.64E-08           23         249 BL1         19         dynamic         all0         200         5.00E+09         382         7.64E-08           26         249 BL1         19         dynamic         all0         200         5.00E+09         322         6.44E-08           27         249 BL1         19         static         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19         static         all0         200         5.00E+09         344         6.88E-08           30         249 BL2         36         dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36         static         all1         200         5.00E+09         416	deg incidence	6.50E-08	325	5.00E+09	200	all1	dynamic	2	249 bulk	18
21         249 bulk         2         static         all0         200         5.00E+09         364         7.28E-08         80 deg in           22         249 BL2         32         dynamic         all1         200         5.00E+09         332         6.64E-08           23         249 BL2         32         static         all1         200         5.00E+09         382         7.64E-08           26         249 BL1         19         dynamic         all0         200         5.00E+09         322         6.44E-08           27         249 BL1         19         dynamic         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19         static         all1         200         5.00E+09         344         6.88E-08           30         249 BL2         36         dynamic         all1         200         5.00E+09         330         6.64E-08           31         249 BL2         36         dynamic         all0         200         5.00E+09         330         6.60E-08           32         249 BL2         36         static         all1         200         5.00E+09         416         8.32E-08 </td <td>deg incidence</td> <td>6.66E-08</td> <td>333</td> <td>5.00E+09</td> <td>200</td> <td>all1</td> <td>static</td> <td>2</td> <td>249 bulk</td> <td>19</td>	deg incidence	6.66E-08	333	5.00E+09	200	all1	static	2	249 bulk	19
22         249 BL2         32 dynamic         all1         200         5.00E+09         332         6.64E-08           23         249 BL2         32 static         all1         200         5.00E+09         382         7.64E-08           26         249 BL1         19 dynamic         all0         200         5.00E+09         314         6.28E-08           27         249 BL1         19 static         all1         200         5.00E+09         344         6.88E-08           29         249 BL1         19 static         all0         200         5.00E+09         332         6.64E-08           30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         330         6.60E-08           31         249 BL2         36 static         all1         200         5.00E+09         310         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         390         7.80E-08           32         249 BL2         36 static         all0         200         5.00E+09         390	deg incidence	7.50E-08	375	5.00E+09	200	all0	dynamic	2	249 bulk	20
23         249 BL2         32         static         all1         200         5.00E+09         382         7.64E-08           26         249 BL1         19         dynamic         all0         200         5.00E+09         322         6.44E-08           27         249 BL1         19         static         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19         static         all0         200         5.00E+09         344         6.88E-08           29         249 BL1         19         static         all0         200         5.00E+09         332         6.64E-08           30         249 BL2         36         dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36         static         all1         200         5.00E+09         410         8.20E-08           32         249 BL2         36         static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36         static         all0         200         5.00E+09         323         6.46E-08           34 <td>deg incidence</td> <td>7.28E-08</td> <td>364</td> <td>5.00E+09</td> <td>200</td> <td>all0</td> <td>static</td> <td>2</td> <td>249 bulk</td> <td>21</td>	deg incidence	7.28E-08	364	5.00E+09	200	all0	static	2	249 bulk	21
26         249 BL1         19 dynamic         all0         200         5.00E+09         322         6.44E-08           27         249 BL1         19 dynamic         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19 static         all1         200         5.00E+09         332         6.64E-08           30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         330         6.60E-08           32         249 BL2         36 static         all1         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all0         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           37         187 bulk         51 static         all1         200         5.00E+09         369		6.64E-08	332	5.00E+09	200	all1	dynamic	32	249 BL2	22
26         249 BL1         19 dynamic         all0         200         5.00E+09         322         6.44E-08           27         249 BL1         19 dynamic         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19 static         all1         200         5.00E+09         344         6.88E-08           30         249 BL2         36 dynamic         all0         200         5.00E+09         330         6.64E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         330         6.60E-08           32         249 BL2         36 static         all1         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           37         187 bulk         51 static         all1         200         5.00E+09         369		7.64E-08	382	5.00E+09	200	all1	static	32	249 BL2	23
27         249 BL1         19 dynamic         all1         200         5.00E+09         314         6.28E-08           28         249 BL1         19 static         all1         200         5.00E+09         344         6.88E-08           29         249 BL1         19 static         all0         200         5.00E+09         332         6.64E-08           30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           36         187 bulk         51 static         all0         200         5.00E+09         343         6.86E-08           37         187 bulk         51 static         all1         200         5.00E+09         369		6.44E-08	322	5.00E+09	200	all0	dynamic	19	249 BL1	26
28         249 BL1         19 static         all1         200         5.00E+09         344         6.88E-08           29         249 BL1         19 static         all0         200         5.00E+09         332         6.64E-08           30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           36         187 bulk         51 dynamic         all0         200         5.00E+09         343         6.86E-08           37         187 bulk         51 static         all1         200         5.00E+09         369         7.38E-08           38         187 bulk         51 static         all0         200         5.00E+09         337		6.28E-08			200	all1	dynamic	19	249 BL1	27
29         249 BL1         19 static         all0         200         5.00E+09         332         6.64E-08           30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           36         187 bulk         51 dynamic         all0         200         5.00E+09         323         6.46E-08           37         187 bulk         51 static         all1         200         5.00E+09         343         6.86E-08           38         187 bulk         51 static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82 dynamic         all1         200         5.00E+09         325							•			28
30         249 BL2         36 dynamic         all1         200         5.00E+09         330         6.60E-08           31         249 BL2         36 dynamic         all0         200         5.00E+09         410         8.20E-08           32         249 BL2         36 static         all1         200         5.00E+09         416         8.32E-08           33         249 BL2         36 static         all0         200         5.00E+09         390         7.80E-08           34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           36         187 bulk         51 dynamic         all0         200         5.00E+09         343         6.86E-08           37         187 bulk         51 static         all1         200         5.00E+09         369         7.38E-08           38         187 bulk         51 static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82 dynamic         all1         200         5.00E+09         325         6.50E-08           40         187 BL2         82 static         all1         200         5.00E+09         308					200	all0			249 BL1	29
31       249 BL2       36 dynamic       all0       200       5.00E+09       410       8.20E-08         32       249 BL2       36 static       all1       200       5.00E+09       416       8.32E-08         33       249 BL2       36 static       all0       200       5.00E+09       390       7.80E-08         34       187 bulk       51 dynamic       all1       200       5.00E+09       323       6.46E-08         36       187 bulk       51 dynamic       all0       200       5.00E+09       343       6.86E-08         37       187 bulk       51 static       all1       200       5.00E+09       369       7.38E-08         38       187 bulk       51 static       all0       200       5.00E+09       369       7.38E-08         39       187 BL2       82 dynamic       all1       200       5.00E+09       325       6.50E-08         40       187 BL2       82 dynamic       all0       200       5.00E+09       309       6.18E-08         41       187 BL2       82 static       all1       200       5.00E+09       333       6.66E-08         44       187 BL1       66 dynamic       all1       200					200	all1	dynamic	36		30
32       249 BL2       36 static       all1       200       5.00E+09       416       8.32E-08         33       249 BL2       36 static       all0       200       5.00E+09       390       7.80E-08         34       187 bulk       51 dynamic       all1       200       5.00E+09       323       6.46E-08         36       187 bulk       51 dynamic       all0       200       5.00E+09       343       6.86E-08         37       187 bulk       51 static       all1       200       5.00E+09       369       7.38E-08         38       187 bulk       51 static       all0       200       5.00E+09       337       6.74E-08         39       187 BL2       82 dynamic       all1       200       5.00E+09       325       6.50E-08         40       187 BL2       82 dynamic       all0       200       5.00E+09       309       6.18E-08         41       187 BL2       82 static       all1       200       5.00E+09       333       6.66E-08         43       187 BL1       66 dynamic       all1       200       5.00E+09       347       6.94E-08         45       187 BL1       66 static       all1       200							·			31
33       249 BL2       36 static       all0       200       5.00E+09       390       7.80E-08         34       187 bulk       51 dynamic       all1       200       5.00E+09       323       6.46E-08         36       187 bulk       51 dynamic       all0       200       5.00E+09       343       6.86E-08         37       187 bulk       51 static       all1       200       5.00E+09       369       7.38E-08         38       187 bulk       51 static       all0       200       5.00E+09       337       6.74E-08         39       187 BL2       82 dynamic       all1       200       5.00E+09       325       6.50E-08         40       187 BL2       82 dynamic       all0       200       5.00E+09       309       6.18E-08         41       187 BL2       82 static       all1       200       5.00E+09       308       6.16E-08         43       187 BL1       66 dynamic       all1       200       5.00E+09       337       6.94E-08         45       187 BL1       66 dynamic       all0       200       5.00E+09       354       7.08E-08         46       187 BL1       66 static       all1       200							·			32
34         187 bulk         51 dynamic         all1         200         5.00E+09         323         6.46E-08           36         187 bulk         51 dynamic         all0         200         5.00E+09         343         6.86E-08           37         187 bulk         51 static         all1         200         5.00E+09         369         7.38E-08           38         187 bulk         51 static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82 dynamic         all1         200         5.00E+09         325         6.50E-08           40         187 BL2         82 dynamic         all0         200         5.00E+09         309         6.18E-08           41         187 BL2         82 static         all1         200         5.00E+09         308         6.16E-08           43         187 BL1         66 dynamic         all1         200         5.00E+09         347         6.94E-08           45         187 BL1         66 dynamic         all0         200         5.00E+09         354         7.08E-08           46         187 BL1         66 static         all1         200         5.00E+09         360					200	all0	static	36		33
36         187 bulk         51 dynamic         all0         200         5.00E+09         343         6.86E-08           37         187 bulk         51 static         all1         200         5.00E+09         369         7.38E-08           38         187 bulk         51 static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82 dynamic         all1         200         5.00E+09         325         6.50E-08           40         187 BL2         82 dynamic         all0         200         5.00E+09         309         6.18E-08           41         187 BL2         82 static         all1         200         5.00E+09         308         6.16E-08           43         187 BL1         66 dynamic         all0         200         5.00E+09         333         6.66E-08           44         187 BL1         66 dynamic         all1         200         5.00E+09         354         7.08E-08           45         187 BL1         66 static         all1         200         5.00E+09         351         6.62E-08           47         187 BL1         66 static         all0         200         5.00E+09         360										
37         187 bulk         51 static         all1         200         5.00E+09         369         7.38E-08           38         187 bulk         51 static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82 dynamic         all1         200         5.00E+09         325         6.50E-08           40         187 BL2         82 dynamic         all0         200         5.00E+09         309         6.18E-08           41         187 BL2         82 static         all1         200         5.00E+09         308         6.16E-08           43         187 BL2         82 static         all0         200         5.00E+09         333         6.66E-08           44         187 BL1         66 dynamic         all1         200         5.00E+09         347         6.94E-08           45         187 BL1         66 dynamic         all0         200         5.00E+09         354         7.08E-08           46         187 BL1         66 static         all1         200         5.00E+09         360         7.20E-08           47         187 BL1         66 static         all0         200         5.00E+09         360							·			36
38         187 bulk         51         static         all0         200         5.00E+09         337         6.74E-08           39         187 BL2         82         dynamic         all1         200         5.00E+09         325         6.50E-08           40         187 BL2         82         dynamic         all0         200         5.00E+09         309         6.18E-08           41         187 BL2         82         static         all1         200         5.00E+09         308         6.16E-08           43         187 BL2         82         static         all0         200         5.00E+09         333         6.66E-08           44         187 BL1         66         dynamic         all1         200         5.00E+09         347         6.94E-08           45         187 BL1         66         dynamic         all0         200         5.00E+09         354         7.08E-08           46         187 BL1         66         static         all1         200         5.00E+09         360         7.20E-08           47         187 BL1         66         static         all0         200         5.00E+09         360         7.20E-08           48										
39     187 BL2     82 dynamic     all1     200     5.00E+09     325     6.50E-08       40     187 BL2     82 dynamic     all0     200     5.00E+09     309     6.18E-08       41     187 BL2     82 static     all1     200     5.00E+09     308     6.16E-08       43     187 BL2     82 static     all0     200     5.00E+09     333     6.66E-08       44     187 BL1     66 dynamic     all1     200     5.00E+09     347     6.94E-08       45     187 BL1     66 dynamic     all0     200     5.00E+09     354     7.08E-08       46     187 BL1     66 static     all1     200     5.00E+09     360     7.20E-08       47     187 BL1     66 static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2 dynamic     all1     104.2     4.81E+09     308     6.40E-08										
40       187 BL2       82 dynamic       all0       200       5.00E+09       309       6.18E-08         41       187 BL2       82 static       all1       200       5.00E+09       308       6.16E-08         43       187 BL2       82 static       all0       200       5.00E+09       333       6.66E-08         44       187 BL1       66 dynamic       all1       200       5.00E+09       347       6.94E-08         45       187 BL1       66 dynamic       all0       200       5.00E+09       354       7.08E-08         46       187 BL1       66 static       all1       200       5.00E+09       331       6.62E-08         47       187 BL1       66 static       all0       200       5.00E+09       360       7.20E-08         48       249 bulk       2 dynamic       all1       104.2       4.81E+09       308       6.40E-08										
41       187 BL2       82 static       all1       200       5.00E+09       308       6.16E-08         43       187 BL2       82 static       all0       200       5.00E+09       333       6.66E-08         44       187 BL1       66 dynamic       all1       200       5.00E+09       347       6.94E-08         45       187 BL1       66 dynamic       all0       200       5.00E+09       354       7.08E-08         46       187 BL1       66 static       all1       200       5.00E+09       331       6.62E-08         47       187 BL1       66 static       all0       200       5.00E+09       360       7.20E-08         48       249 bulk       2 dynamic       all1       104.2       4.81E+09       308       6.40E-08										
43     187 BL2     82 static     all0     200     5.00E+09     333     6.66E-08       44     187 BL1     66 dynamic     all1     200     5.00E+09     347     6.94E-08       45     187 BL1     66 dynamic     all0     200     5.00E+09     354     7.08E-08       46     187 BL1     66 static     all1     200     5.00E+09     331     6.62E-08       47     187 BL1     66 static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2 dynamic     all1     104.2     4.81E+09     308     6.40E-08										
44     187 BL1     66 dynamic     all1     200     5.00E+09     347     6.94E-08       45     187 BL1     66 dynamic     all0     200     5.00E+09     354     7.08E-08       46     187 BL1     66 static     all1     200     5.00E+09     331     6.62E-08       47     187 BL1     66 static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2 dynamic     all1     104.2     4.81E+09     308     6.40E-08										
45     187 BL1     66 dynamic     all0     200     5.00E+09     354     7.08E-08       46     187 BL1     66 static     all1     200     5.00E+09     331     6.62E-08       47     187 BL1     66 static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2 dynamic     all1     104.2     4.81E+09     308     6.40E-08										
46     187 BL1     66     static     all1     200     5.00E+09     331     6.62E-08       47     187 BL1     66     static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2     dynamic     all1     104.2     4.81E+09     308     6.40E-08							•			
47     187 BL1     66 static     all0     200     5.00E+09     360     7.20E-08       48     249 bulk     2 dynamic     all1     104.2     4.81E+09     308     6.40E-08										
48 249 bulk 2 dynamic all1 104.2 4.81E+09 308 6.40E-08										
49   249 bulk   2   dynamic   all0   104.2   5.00E+09   334   6.68E-08		6.68E-08			104.2	all0	dynamic		249 bulk	
50 249 bulk 2 static all1 104.2 5.00E+09 402 8.04E-08							·			
50 249 bulk 2 static all0 104.2 1.09E+09 91 8.33E-08										